

Shores of Change: How Warming is Reshaping Intertidal Communities

Rocky intertidal ecosystems are among the most biologically rich on Earth—and they are changing rapidly. Since 2013, NETN has monitored intertidal communities at Acadia and Boston by revisiting permanent plots and transects.

KEY TAKEAWAY:

- Warming is reorganizing intertidal communities in complex, species-specific ways, especially in transition zones and during winter warming — not simply causing universal decline. Responses vary by species and park.

THE GULF OF MAINE IS WARMING 3X AS FAST AS THE GLOBAL AVERAGE.

Based on Gulf of Maine Research Institute (GMRI) findings

SEA LEVEL RISE IS ACCELERATING

HISTORICAL RISE (LONG-TERM AVERAGE)	RECENT ACCELERATION (IN RECENT DECADES)
~1.9–2.1 mm per year	~3–4 mm per year

NOAA tide gauges (Portland & Boston)

Zones of the Rocky Intertidal

- HIGH ZONE**
Barnacles dominate.
- MID ZONE**
Canopy-forming algae (*Fucus*, *Ascophyllum*) dominate.
- LOW ZONE**
Red algae and mussels dominate.
- TRANSITION ZONES**
Where communities overlap, interact, and change the most.

More exposure (drier, warmer)
More immersion (wetter, cooler)

Warming and sea level rise are reshaping these zones over time

Boundaries are shifting

Communities overlap

Change is ongoing

HOW WE TRACK CHANGE OVER TIME

HOW MONITORING WORKS

- Permanent plots established in 2012**
Fixed plots were placed in dominant species zones (e.g., barnacle, *Fucus*, etc.)
- We revisit the same plots every year**
These plots stay in the same exact locations year after year.
- We measure change at that place**
Changes reflect how those communities shift at that location and elevation.

DEFINING “STABILITY”

How much has a community changed over time? The more similar, the more stable it's considered to be.

2013
Bass Harbor (ACAD)
Barnacle Plot 1 in 2013

2024
Bass Harbor (ACAD)
Barnacle Plot 1 in 2024
Same plot, 11 years later

EXAMPLE: FUCUS ZONE PLOT AT ACADIA NATIONAL PARK

Important Note
A species may increase in one zone while declining at other elevations.

PERMANENT PLOTS
White PVC frames mark fixed plots.

WHAT THE DATA SHOW

HOW COMMUNITIES ARE RESPONDING

Canopy-forming species (*Fucus*, *Ascophyllum*) show the highest stability.

Barnacles, mussels, and red algae are more dynamic and variable.

Communities are shifting—not collapsing.

- Barnacles are being displaced or becoming covered by canopy species.
- Fucus* is becoming more abundant and occurring higher on the shore.
- Mid-elevation communities of *Ascophyllum* are the most stable.
- Mussels (only monitored in ACAD) are increasingly an understory species.
- Red algae plots, esp. the lowest ones, are becoming increasingly subtidal in composition.

COMMUNITY BOUNDARIES ARE REORGANIZING
Some communities can expand upward, while others become compressed (e.g. barnacles).

WHY IT MATTERS

- Habitats change**
Shifting communities alter habitat and food availability.
- New stable states are possible**
Disturbance can reorganize communities and create new stable states - such as from *Fucus*-dominated to mussel-dominated.
- Some communities are becoming less stable**
Greater variability can make communities less resilient as warming increases.
- Warming pushes systems to thresholds**
Warming and disturbance can push species past temperature thresholds that they cannot survive.

TRANSITION ZONES ARE MOST DYNAMIC

Communities are least stable at the edges of zones and where bands transition.

These transition areas are especially vulnerable to change.

THE BIG PICTURE

A chain reaction linked to warming.

1. WARMING INCREASES

The Gulf of Maine is warming rapidly—especially in winter (cold extremes).

2. VARIABILITY RISES

More year-to-year variability / in community composition.

3. RESILIENCE DECLINES

Communities become less able to resist disturbance.

4. NEW STATES EMERGE

Disturbance can push communities into new stable states over time.

WHY LONG-TERM MONITORING MATTERS

Few long-term datasets exist for rocky intertidal systems. Tracking the same places over time reveals real change and helps us understand and prepare for the future.

Coastal Water Temperature Patterns at Acadia and Boston Harbor

Acadia is cooler and more stable; Boston Harbor is warmer and more seasonally variable. Both regions show warming trends.

ACADIA NATIONAL PARK

Cooler & More Stable
Smaller seasonal swings in water temperature

SEASONAL PATTERNS WITH LONG-TERM WARMING

Lines show temperature percentiles across days within each year. (Top 10% warmest days, median, bottom 10% coolest days)

TEMPERATURE RANGE: ~30°F

- More consistent cool conditions
- Less month-to-month variability
- Lower temperature extremes

BOSTON HARBOR ISLANDS NATIONAL PARK AREA

Warmer & More Variable
Larger seasonal swings in water temperature

SEASONAL PATTERNS WITH LONG-TERM WARMING

Lines show temperature percentiles across days within each year. (Top 10% warmest days, median, bottom 10% coolest days)

TEMPERATURE RANGE: ~40°F

- Warmer conditions year-round
- Greater month-to-month variability
- Stronger seasonal contrast

WHAT CONTROLS INTERTIDAL COMMUNITY STABILITY?

Stability varies by dominant community species, elevation, and temperature—and differs between parks.

1 ELEVATION CHANGES ENVIRONMENTAL STRESS

Environmental stress increases higher on the shore

MORE STRESS (high shore)

- Hotter
- Drier
- More exposure
- More thermal stress

LESS STRESS (low shore)

- Cooler
- Wetter
- More submerged
- Less thermal stress

Stressed, higher shore areas are less likely to be able to provide food for filter feeders like barnacles.

2 TEMPERATURE DRIVES CHANGE

Stability declines as temperatures **increase**, especially during winter warming.

WARMER CONDITIONS = LOWER STABILITY

Stability declines as temperatures increase across parks and communities.

COLDEST CONDITIONS MATTER MOST

Warming of the coldest conditions (e.g., winter temperatures) has the strongest link to declining stability.

Stronger
Weaker

10th (percentile) 50th (median) 90th (percentile)

Temperature Conditions

3 EFFECTS VARY BY PARK AND SPECIES

DOMINANT COMMUNITY	ACADIA NATIONAL PARK (cooler waters)	BOSTON HARBOR ISLANDS (warmer waters)
BARNACLES (<i>Semibalanus</i>)	Greatest loss of similarity as low temperatures rise. ↓	Greatest loss of similarity as low temperatures rise. ↓
FUCUS / ASCOPHYLLUM (canopy algae)	Moderately less similar as temperatures rise. ↓	Moderately less similar as temperatures rise. ↓
RED ALGAE (<i>Chondrus/Mastocarpus</i>)	Strong change with warming. ↓	Moderate change with warming. ↓
MUSSELS (<i>Mytilus</i>)	Limited data. Understory species increasing. —	Not monitored. —

Same drivers, different responses.
Stability changes depend on the park, the dominant species, and where communities occur along the shore.

IMPORTANT CONTEXT

ELEVATION IS MEASURED FROM SEA LEVEL.

All elevations are relative to sea level.

AS SEA LEVEL RISES,

fixed plots experience conditions more like lower elevations over time.

LOW-ZONE COMMUNITIES

(e.g., red algae) are first to show impacts.

COLDEST CONDITIONS DRIVE INSTABILITY.

Winter warming has the strongest influence on community stability.

STABILITY IS MEASURED

as similarity of a plot to its baseline community over time (Bray–Curtis).